WHY Multiparametric breast MRI?

Conventional MRI: relatively low specificity

HOW?

Diffusion weighted imaging: IVIM, DKI…
Pharmacokinetic analysis: T1-weighted perfusion…
Metabolic status: MRS…

WHAT TO DO?

Discrimination of benign and malignant tumors
Prognosis prediction
NACT response assessment

The following technologies will be discussed in this lecture
1. IVIM
2. DKI
3. MRS

IVIM: Help to differentiate malignant breast lesions from benign lesions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Malignant lesions versus benign lesions</th>
<th>ADC (mm²/s)</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC (mm²/s)</td>
<td>0.72 (0.08)</td>
<td>0.65</td>
<td>0.71</td>
<td>1.54 x 10⁻³</td>
<td></td>
</tr>
<tr>
<td>D* (mm²/s)</td>
<td>0.75 (0.08)</td>
<td>0.85</td>
<td>0.64</td>
<td>1.52 x 10⁻³</td>
<td></td>
</tr>
<tr>
<td>f (probability, unitless)</td>
<td>0.79 (0.07)</td>
<td>0.73</td>
<td>0.86</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>D (mm²/s)</td>
<td>0.85 (0.08)</td>
<td>0.85</td>
<td>0.86</td>
<td>0.58</td>
<td></td>
</tr>
</tbody>
</table>

IVIM: Microscopic motion of water molecules detected by DWI is influenced not only by diffusion of water molecules, affected by the structures of the tissue, but also by microcirculation of blood in the capillary network.

Accordingly, the signal attenuation on monoeXponential DWI sometimes does not represent a linear relationship and it is difficult to calculate the accurate ADC value.

Intravoxel incoherent motion (IVIM), first described by Le Bihan et al., can separate estimation of tissue perfusion and diffusion using multi-b-value DWI with a biexponential curve fitting

The bi-exponential model:

\[ S(b) = S_0 [f_p \exp(-bD_p) + (1 - f_p) \exp(-bD_g)] \]

S: signal intensity
D: true diffusion coefficient
f: perfusion fraction
D*: pseudo-diffusion

4. Quantitative DCE

The potential application of IVIM:

- Differentiate malignant breast lesions from benign lesions
- Correlation with immunohistochemical index of breast cancer
- Monitor response to neoadjuvant chemotherapy in locally advanced breast cancer

**Patient data:** 59 y/o, female  
**Presentation:** mass in left breast  
**Pathology:** IDC

**Patient data:** 15 y/o, female  
**Presentation:** mass in left breast  
**Pathology:** Fibroadenoma

**IVIM: Correlation with IHC index**

**Monitor response to neoadjuvant chemotherapy in locally advanced breast cancer**

**Patient data:** 51 y/o, female, with IDC, pCR(eventually)

Diffusion Kurtosis Imaging (DKI)

- Conventional diffusion MRI techniques always assume a Gaussian diffusion (i.e., free and unrestricted diffusion) of water protons.
- Measurement of **diffusional non-Gaussianity** (i.e., diffusion kurtosis), a measure of diffusional heterogeneity, by means of diffusion kurtosis imaging (DKI) may allow improved characterization of water diffusion properties in the tumor microenvironment.

DKI showed **higher specificity and AUC** than did conventional DWI for assessment of benign and malignant breast lesions. Radiology 2015;277:46-55.

Magnetic resonance spectroscopy (MRS)

- non-invasive
- assess biochemical composition of breast lesions

**Choline** is a precursor of the phosphatidylcholine that makes up cell membranes, and its elevated signal reflects increased membrane synthesis.

**¹H MRS** allows the detection of total composite choline compounds (tCho) at 3.2 ppm in most breast cancers.

**The dynamic change in signal intensity** of DCE MRI is used to calculate functional parameters related to tissue flow and leakage of the contrast agent from...
the intravascular to the extracellular space.

- **Angiogenesis**: key element of tumor growth and metastasis. For tumor ≥ 12 mm in diameter, neovascularization becomes a necessity.

- Potential applications of Quantitative DCE-MRI:
  - Discrimination of benign & malignant tumors
  - Prediction & monitoring of malignant grades
  - Response prediction & assessment of neoadjuvant treatment
  ...
Technology of digital breast tomosynthesis (DBT)

An X-ray mammography technique in which tomographic images of the breast are reconstructed from multiple low-dose projection images acquired by moving the X-ray tube in an arc over a limited angular range (15–60°).

Results from current clinical studies with DBT

1. Recent studies in screening populations show a statistically significant reduction in recall rate with two-view DBT plus full-field digital mammography (FFDM) compared with two-view FFDM.
2. Prospective trials in screening population from Europe show a statistically significant increase in cancer detection rate with two-view DBT plus FFDM compared with two-view FFDM, and retrospective reader studies from the United States show either a significant or a nonsignificant increase.
3. Retrospective observational studies show either noninferiority or superiority of DBT compared with mammography in terms of area under the curve or other equivalent figures of merit.

Advanced application of DBT

1. Computer-aided detection to 2D DBT projections
2. Biopsy-guidance devices compatible with DBT
3. Multimodality imaging system that include DBT: Combining DBT with automated ultrasound, radionuclide imaging or near-infrared imaging

Pros and cons of DBT

Pros

1. Diagnostic accuracy ↑, false positive ↓, recall rate ↓: Overcome the primary limitation of standard FFDM that arises from overlapping fibroglandular breast tissue
2. Sensitivity and specificity ↑: Radiation exposure (Similar to or less than that from conventional mammography)

Cons

1. Motion artifacts, Large calcifications cause significant artifacts
2. Additional reading time, IT storage and connectivity
3. Over-diagnosis, Cost effectiveness

References

What is CAD? Computer aided detection or diagnosis system

A technology designed to decrease observational oversights -and thus the false negative rates- of physicians interpreting medical images.

1. Computer aided detection (CADe)
   - help radiologists avoid overlooking a cancer
   - used in screening mammography \(\rightarrow\) Sensitivity <

2. Computer aided diagnosis (CADx)
   - help radiologists decide whether a biopsy is warranted
   - used in diagnostic mammography or ultrasound \(\rightarrow\) Specificity <

SECTION I: CAD of mammography
SECTION II: CAD of breast sonography
SECTION III: CAD of breast MRI

SECTION I: CAD of mammography

1. Quality of CAD system
   - Increase radiologists' sensitivity by 10% with increased in the recall rate.
   - The sensitivity of the CAD systems is greater for detecting calcifications than for detecting masses.

2. What can you do to make sure you are using CAD correctly?
   - Don’t change your readings to BIRADS 1 or 2 based on CAD marks. CAD is intended to increase sensitivity, not improve specificity.
   - Consciously pay attention to the CAD marks and re-evaluate every marks area.
   - When you change your mind and decide to recall a patient based on CAD marks, find out what happens at work-up to those patients.
   - Works as diligently to improve your CAD performance as you do to improve your recommendations for biopsy.

SECTION II: CAD of breast sonography

The role of CAD in sonography is to provide the second opinion for the interpretation of a sonographically detected breast tumor and to improve diagnostic confidence

1. CADx with “Knowledge” based
   - Based on the BI-RADS lexicon
   - Computerized BI-RADS features

2. CADx with “statistic” based
   - Decision tree
   - Artificial neural network
   - Support vector machine
   - Random forest

SECTION III: CAD of breast MRI

Computer-aided detection (CADe) and diagnosis systems (CADx) could provide an accurate and time efficient support to the interpretation of breast MR images by improving lesion detection and differentiation between malignant and benign nodules.

- Computer-aided detection (CAD) of breast MRI may be helpful to evaluate both patients with primary malignancy & those following NAC
- Clinical evidence is insufficient to increase the accuracy of breast MRI
- Careful interpretation using CAD would be needed for assessment of MR-detected lesions

What is deep learning?
Machine learning is a subfield of computer science
that evolved from the study of pattern recognition and computational learning theory in artificial intelligence.

**Deep learning** is a branch of machine learning based on a set of algorithms that attempt to model high-level abstractions in data by using multiple processing layers, with complex structures or otherwise, composed of multiple non-linear transformations

**Conclusion**
- Mammography CAD–CAd: increased sensitivity
- Ultrasound CAD–CAdx: knowledge based & statistics based
- MR CAD–CAd & CADx: morphology & dynamic kinetics

**References**

RESULTS: 128,756 cases were valid among 130,537 cases. There were 400 breast cancer (322 invasive and 78 in situ) patients registered within 1 year after screening. Types of mammography were film in 33,976 (26.4%), CR in 41,690 (32.4%), and digital in 53,090 (41.2%). DM showed better performance than film and CR in RR (14.8 vs. 24.8 and 19.8%), CDR (3.43 vs. 2.24 and 2.11), PPV1 (2.3 vs. 0.9 and 1.1%), specificity (85.5 vs. 75.3 and 80.3%), and FPR (14.5 vs. 24.7 and 19.7%) (p < 0.0001); but not in sensitivity (86.3 vs. 87.4 and 86.3%) (p = 0.8190) and ICR (0.06 vs. 0.04 and 0.04) (p = 1.1873). Use of CAD in DM showed better performance in RR (10.3 vs. 19.5%), PPV1 (3.4 vs. 1.7%), specificity (90.0 vs. 80.7%), and FPR (10.0 vs. 19.3%) (p < 0.0001); but not in CDR (3.52 vs. 3.33) (p = 0.7050), sensitivity (87.2 vs. 85.3) (p = 0.6949), and ICR (0.06 vs. 0.07) (p = 0.5724). Use of DRW showed better performance in RR (10.6 vs. 17.6%), PPV1 (3.4 vs. 1.9%), and specificity (89.7 vs. 82.6%), and FPR (10.3 vs. 17.4%) (p < 0.0001); but not in CDR (3.56 vs. 3.34) (p = 0.6736), sensitivity (87.2 vs. 85.6) (p = 0.7388), and ICR (0.06 vs. 0.07) (p = 0.6838). CONCLUSION: DM and use of CAD and DRW showed better performance in RR, PPV1, specificity, and FPR of screening mammography. Application of DM, CAD, and DRW seems to be helpful in quality improvement of the NCSP in Korea.

SS 07 BR-02 09:50
Performance of screening mammography by characteristics of radiologists in the national cancer screening program in Korea
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PURPOSE: To evaluate performance of screening mammography by characteristics of radiologists in the national cancer screening program in Korea. MATERIALS AND METHODS: Ten university-affiliated hospitals participating in National Cancer Screening Program were enrolled in this retrospective study. We collected results of mammography performed between 2005 and 2010 and matched them with data base of National Health Insurance Service. We extracted invasive and in situ cancer patients registered within 1 year after screening. Pre-existing breast cancer patients, examinees performed interstitial mammoplasty, and unmatched cases were excluded. We calculated recall rate (RR), cancer detection rate (CDR) per 1,000 screening, positive predictive value (PPV1), sensitivity, specificity, false positive rate (FPR), and interval cancer rates (ICR) and compared them according to types of equipments and use of CAD and DRW in digital mammography (DM).
Advanced breast ultrasound

**SS 07 BR-03  10:00**

**Effect of calcifications on shear wave elastography in evaluating breast lesions**

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**PURPOSE:** To investigate the effect of calcifications on shear wave elastography (SWE) in evaluating breast lesions.

**MATERIALS AND METHODS:** We retrospectively reviewed ultrasound (US) images of 807 consecutive patients who had breast US with SWE between October 2013 and March 2014. We excluded the patients who had no mammography (n = 54) or no measured E\text{mean} (n = 51) or no follow up data (n = 47), and the patients who had neoadjuvant chemotherapy before the US examination (n = 24). Finally 631 patients with 673 breast lesions were included in this study. We analyzed US findings of the lesions: type (mass or non-mass), size, BI-RADS category and the elasticity score (E\text{mean}) measured at the stiffer area of the lesions. And we compared the E\text{mean} between breast lesions with calcifications and without calcifications in three subgroups: benign lesions, in situ carcinoma, and invasive carcinoma. We also analyzed the influence of other US factors on the E\text{mean} of the breast lesions.

**RESULTS:** Breast lesions were confirmed by histologically (n = 409) or by follow up images for more than 2 years (n = 264). Calcifications were present in 25.3% (170/673) lesions and absent in 74.7% (503/673) lesions. E\text{mean} was 33.9 kPa in overall benign lesions; 62.8 kPa in benign lesions with calcifications and 29.8 kPa in benign lesions without calcifications (p = 0.000). In situ carcinoma showed 97.0 kPa; lesions with calcifications showed 114.6 kPa while lesions without calcifications showed 52.8 kPa (p = 0.037). In invasive carcinoma, the overall E\text{mean} was 157.6 kPa, and E\text{mean} of lesions with calcifications and without calcifications were 171.9 kPa and 146.4 kPa (p = 0.018). Other US factors such as lesion type (mass or non-mass), size, Breast Imaging Reporting and Data System (BI-RADS) final category showed no statistically significant correlations with elasticity score in the lesions with same pathologic results.

**CONCLUSION:** The presence of calcifications significantly increased the E\text{mean} of breast lesions. Elastography should be carefully interpreted considering the presence of calcifications within the lesions.

**SS 07 BR-04  10:10**

**Clinical utility of real-time MR-navigated ultrasound with supine breast MRI for suspicious enhancing lesions not identified on second-look ultrasound**

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This study evaluated the usefulness of MR-navigated US for evaluation of MRI-detected lesions not visible on second-look US and analyzed differences of the lesion to nipple distance between supine and prone position. Of the 831 consecutive patients who were diagnosed as breast cancer and examined with breast MRI from June 2013 to September 2015, we included 40 lesions in 37 patients who underwent MR-navigated US for MRI-detected lesions which were not visible on second-look US. First MRI was performed in prone position using a 1.5-T imager and second MRI was performed in a supine position for MR-navigated US. Of 40 lesions, 31 (78%) were identified with MR-navigated US, whereas 5 (13%) lesions disappeared on supine MRI and 4 (10%) showed no correlation on MR-navigated US. Of 31 lesions with pathologic confirmation, 7 (23%) were malignant, 2 (6%) were high risk lesions and 22 (71%) were benign lesions. Comparing the US findings of benign and malignant lesions, orientation of the lesion
showed significant difference (p = 0.045), whereas lesion shape, margin and echo pattern were not significantly different between two groups (p = 0.088, p = 0.094 and p = 0.412, respectively). Median difference of lesion to nipple distance on supine and prone MRI was 8 mm (0–34 mm) in horizontal direction and 5 mm (0–39.5 mm) in vertical direction. Thirteen lesions showed more than 1 cm difference in both horizontal and vertical direction. In conclusion, MR-navigated US is useful for the evaluation of MRI-detected lesions which were not visible on second-look US in breast cancer patients.

SS 07 BR-05 10:20
Superb micro-vascular imaging (SMI) in distinguishing benign from and malignant solid masses at breast US: comparison with contrast-enhanced US
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PURPOSE: To prospectively investigate the effect of Superb Micro-Vascular Imaging (SMI) in distinguishing benign from malignant solid breast masses by comparing with contrast-enhanced ultrasound (CEUS).

MATERIALS AND METHODS: Forty female patients who underwent US-guided core needle biopsy for 40 suspicious breast masses and gave written informed consent to this investigation were finally included. Before the biopsy, SMI and CEUS examinations were done in all patients using Aplio 500 US equipment (Toshiba Medical Systems Corporation, Japan) and SonoVue contrast agent (Braconn, Italy). Both quantitative and qualitative parameters were evaluated in SMI (vascular index-% area of vessel signal in the total lesion; qualitative parameters including morphology and distribution of vessels and presence of penetrating vessel) and CEUS (time intensity curve analysis-peak intensity [PI], time to peak [TTP], mean transit time, slope, area under the curve [AUC]; qualitative parameters including degree, margin, and order of enhancement and the presence of internal homogeneity, penetrating vessel, and perfusion defect). Each parameter was compared between benign and malignant masses using student’s T-test and chi-square test. The diagnostic performance of SMI and CEUS was analyzed and compared using logistic regression and the receiver operating characteristic curve (ROC) analysis.

RESULTS: Twenty-four masses were benign and 16 were malignant. On SMI, malignant masses showed higher vascular index (p < 0.001), more frequently branching/shunting vessel (p = 0.047), central vascularity (p = 0.027), and penetrating vessels (p = 0.002). On CEUS, malignant masses demonstrated higher PI (p = 0.073) and AUC (p = 0.057), lower TTP (p = 0.092), more frequent hyperenhancement (p = 0.061), centripetal enhancement (p = 0.022), penetrating vessel (p = 0.053), and perfusion defect (p = 0.018). The area under the ROC curve of SMI and CEUS was 0.857 and 0.898, which was statistically equivalent (p = 0.475).

CONCLUSION: SMI is a valuable Doppler technique in distinguishing benign from malignant solid breast masses and its diagnostic performance was equivalent to CEUS.

SS 07 BR-06 10:30
Dynamic contrast-enhanced MRI perfusion parameters as imaging biomarkers of angiogenesis
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PURPOSE: To investigate the relationship between perfusion parameters and angiogenic and prognostic factors in patients.

MATERIALS AND METHODS: Perfusion parameters (K^trans, k_pec, and v_e) of 81 invasive ductal carcinomas (IDC) were obtained using histogram analysis. Twenty-fifth, 50th and 75th percentile values were calculated and were analyzed for association with microvessel density (MVD), vascular endothelial growth factor (VEGF) and conventional prognostic factors.

RESULTS: Correlation between MVD and v_e50 was positive (r = 0.33, p = 0.002). VEGF expression was negatively associated with ve25 and v_e50 (r = −0.24 and −0.20, p = 0.027 and 0.066, respectively). K^trans50 and v_e50 were higher in tumors larger than 2 cm than in tumors smaller than 2 cm. K^trans50 and k_pec50 were higher in ER-positive tumors than ER-negative tumors. In multivariate analysis, K^trans50 was affected by tumor size and ER expression with 26.9% explanation and v_e50 by MVD and VEGF with 37.2% explanation.
CONCLUSION: There were significant associations between MR perfusion parameters and angiogenic and prognostic factors. $v_{so}$ was associated with MVD and VEGF and $K_{trans}$ with tumor size and the expression of ER. Perfusion parameters are potential imaging biomarkers for prediction of tumor angiogenesis and aggressiveness.

**SS 07 BR-07 10:40**

Intravoxel incoherent motion (IVIM)-derived parameters in diffusion-weighted MRI: association with prognostic factors in invasive ductal carcinoma

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**PURPOSE:** To investigate associations between intravoxel incoherent motion (IVIM) metrics of invasive ductal carcinoma of the breast and prognostic factors.

**MATERIALS AND METHODS:** This retrospective study included a total 82 masses from 72 patients, who underwent 3T breast MRI, IVIM and diffusion weighted imaging. IVIM metrics of pseudodiffusivity ($D_{fast}$), tissue diffusivity ($D_{slow}$), perfusion fraction ($D_{pf}$) were measured using histogram analysis for the whole lesion volume. And then we evaluated associations with conventional prognostic factors, subtypes of breast cancer, angiogenetic molecular markers, and pathologic factors.

**RESULTS:** The $D_{slow}$ 50th, 75th, and 90th percentile metrics showed a decreasing value in the estrogen receptor (ER) - positive group, compared with the ER-negative group ($p < 0.05$). The size of ductal carcinoma in situ (DCIS) component ($< 5\%$) correlated with the significantly higher value of 50th, 75th, 90th percentile and mean of $D_{pf}$ (individually, $p = 0.050, 0.032, 0.027, 0.034$), compared with those of the size of DCIS component ($\geq 5\%$). In addition, heterogeneity metrics (kurtosis and skewness) of $D_{pf}$ also differentiated between DCIS component size $< 5\%$ and $\geq 5\%$ ($p < 0.05$). While any IVIM parameters do not have a good discriminative power with regard to tumor size, lymph node status, vascular endothelial growth factor, and central fibrosis in this study.

**CONCLUSION:** The $D_{slow}$ metrics showed significant differentiation between ER positive and negative groups, and the $D_{pf}$ metrics was significantly associated with the size of DCIS component.
Comparison of the diagnostic performance of synthetic versus acquired high b-value (1500 s/mm²) diffusion-weighted MR images in women with known breast cancers

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PURPOSE: To compare the diagnostic performance of synthetic and acquired high b-value (1500 s/mm²) diffusion weighted images in women with known breast cancers.

MATERIALS AND METHODS: Two radiologists independently reviewed image sets of 117 patients (median age, 48 years; range, 32–77 years) with 145 cancers in both synthetic and acquired b = 1500 s/mm² diffusion weighted images (DWI). The probability of the cancer was scored in a 6-point Likert-type scale. For DWI, a single-shot EPI diffusion sequence (b = 0, 800 s/mm²) was utilized. Synthetic b = 1500 s/mm² (S-b1500) was calculated voxelwise from the ADC and diffusion images. Acquired b = 1500 s/mm² (A-b1500) was additionally acquired for evaluation and comparison. All measurements were performed on a 3T MR system. Jack-knife alternative free-response receiver-operating characteristic (JAFROC), which allows diagnostic performance estimation using single lesion as a statistical unit in a cancer-only population, was used. Sensitivity and specificity were compared using the McNemar’s test.

RESULTS: The JAFROC figures of merit (FOMs) was 0.793 in S-b1500 and 0.787 in A-b1500 but the there was no statistically significant difference (p = 0.708). The sensitivity was higher in S-b1500 (66.7%) than in A-b1500 (55.1%, p = 0.0005) with statistical significance. The specificity in S-b1500 (92.4%) and A-1500 (94.4%, p = 0.3428) did not show statistically significant difference.

CONCLUSION: Synthetic high b-value (1500 s/mm²) DWI has significantly higher sensitivity without significant difference in specificity when compared to acquired high b-value DWI. Synthetic high b-value (1500 s/mm²) DWI may contribute to improve diagnostic performance in breast cancer patients without additional time needed in image acquisition.

Lesion to background signal enhancement ratio on breast MRI is useful in distinguishing presence of residual tumor versus no residual tumor after neoadjuvant chemotherapy

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PURPOSE: To investigate whether the lesion to background signal enhancement ratio (SER) on dynamic contrast enhanced (DCE)-MRI is useful in distinguishing residual tumor versus no residual tumor as well as minimal invasive tumor versus residual DCIS on histopathology after neoadjuvant chemotherapy (NAC).

MATERIALS AND METHODS: Between 2009 and 2015, 861 consecutive women who had undergone NAC, DCE-MRI, and subsequent surgery were identified. Among them, a total of 221 women (mean age, 47.9; range, 26–82 years) with no residual tumor (n = 75), residual DCIS (n = 51) or minimal invasive tumor ≤ 5 mm (n = 95) on histopathology were included. To compare the mean SER (signal intensity of the lesion/signal intensity of normal parenchyma) and lesion size on MRI according to the presence of residual tumor, in multivariate logistic regression analysis were performed. Area under the receiver operating characteristic curve (Az) was used to evaluate performance of SER.

RESULTS: Mean SER of residual tumor (minimal invasive tumor plus DCIS) was higher than that of no residual tumor (1.72 ± 0.40 vs. 1.49 ± 0.32, p < 0.001). Mean SER of residual DCIS was not different that of minimal invasive tumor (1.78 ± 0.36 vs. 1.69 ± 0.41, p = 0.181). Mean MRI lesion size of residual tumor was larger than that of no residual tumor (2.42 ± 1.97 cm vs. 1.37 ± 1.57 cm, p < 0.001). In multivariate analysis, higher SER (OR, 6.206; 95% CI, 2.512–15.331, p < 0.001) and larger lesion size on MRI (OR, 1.576; 95% CI, 1.249–1.988, p < 0.001) were independently
associated with the presence of residual tumor. Az value of SER in distinguishing residual tumor versus no residual tumor was 0.662 (95% CI: 0.595–0.724) with an optimal cut-off point of 1.7 yielding maximal sum of sensitivity and specificity.

CONCLUSION: Lesion to background SER on MRI was useful in distinguishing presence of residual tumor from no residual tumor after NAC, however, it was not useful in distinguishing minimal invasive tumor from residual DCIS.

CONCLUSION: The presence of clustered ring NME was significantly associated with invasive breast cancer and lymph node metastasis.

CLINICAL RELEVANCE: Accurate analysis of patterns of malignant NME on breast MRI helps predict invasiveness and lymph node metastasis.

**SS 13 BR-02 16:10**

Patterns of malignant non-mass enhancement on breast MRI help predict invasiveness and lymph node metastasis: using BI-RADS Lexicon 5th edition

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PURPOSE: To evaluate the clinical significance of the distribution and patterns of malignant non-mass enhancement (NME) on breast MRI by assessing their correlation to the presence of invasion, lymph node metastasis and other histopathologic factors.

MATERIALS AND METHODS: Of 213 patients who underwent breast magnetic resonance imaging (MRI) examinations and had non-mass enhancement from February 2013 to March 2016, 77 women had pathologically proven breast cancer which demonstrated pure malignant NME without mass on MRI and the five ineligible cases were excluded. The 72 malignant NMEs (26 in situ and 46 invasive) in 72 women (age, 35–79 years; mean, 50.1 years) were included in this study. Two radiologists independently assessed the distribution first, and then evaluated each of four internal enhancement patterns of NME (homogeneous, heterogeneous, clumped, and clustered ring) dichotomously according to the Breast Imaging Reporting and Data System (BI-RADS) lexicon 5th edition. Collected data included the tumor size on MRI, presence of necrosis, lymphovascular invasion, hormonal receptor, and HER-2. Chi-square test, Fisher exact test, or Student t test was used to analyze differences of variables by each reviewer.

RESULTS: All two reader’s results showed clustered ring NME to be significantly associated with invasiveness (p = 0.001, 0.000, respectively), lymph node metastasis (p = 0.017, 0.018), and necrosis (p = 0.000, 0.000). Heterogeneous NME was found to be significantly associated with in situ (p = 0.030, 0.033). Furthermore, _in situ_ lesions (5.05 ± 2.51 cm) and invasive lesions (6.25 ± 2.38 cm) significantly differed in size (p = 0.049).

SS 13 BR-03 16:20

Characteristic features and usefulness of MRI in breast cancer in patients over 70 years old: comparison with the group of patients under age 70 and correlation with prognostic factors

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PURPOSE: To evaluate characteristic features of breast MRI in old age patients with breast cancer and compare with that of average age patients and correlate with the prognostic factors of breast cancer.

MATERIALS AND METHODS: We designed a case-control study to compare the MRI features between old and average age groups. A total of 150 breast cancer patients with age over 70 years as the case group and 302 patients with age under 70 years as the control group were included. We performed a retrospective review of the clinical, radiological and pathological features of each group.

RESULTS: The mean age of the patients in the case group was 79.6 years (range, 70 to 94 years) and 54.2 years (range, 40 to 69 years) in the control group. In case group, about 54% of cancer was detected incidentally on screening. The most common clinical symptom was palpable mass (54%) which followed by nipple discharge (5.3%), nipple retraction (2.6%), pain (2%) and nipple erosion (1.3%). In control group, about 54% of cancer was detected palpable mass (33%), nipple discharge (7%), pain (6%), nipple retraction (4%), nipple erosion (1%) and axillary mass (1%), respectively. The most common MRI features in case group and control group were mass or multiple masses (82% vs. 81%) with irregular shape (52% vs. 37%), spiculated margin (47% vs. 34%), heterogeneous enhancement (46% vs. 37%). The shape (p = 0.006), margin (p = 0.026) and T2 signal intensity (p ≤ 0.0001) of the mass, background parenchymal enhancement (p = 0.0007), distribution (p = 0.002) of nonmass enhancement and initial slope of kinetic curve (p = 0.001) were significantly correlated with each group. The tumor size (p = 0.036), expression of PR (p = 0.0001), expression of HER2 (p = 0.039),...
luminal type (p = 0.0008) also showed significant statistical correlation between two groups. Within case group, the irregular mass shape was significant independent predictor of the larger tumor size (> 2 cm) (p = 0.002) and positive expression of HER2 (p < 0.0001). After preoperative MRI, the surgical plan changed in 34 patients (22.7%) in case group and 72 patients (24%) in control group. There was no statistical difference between two groups.

CONCLUSION: Breast cancer in women over 70 years old often presents as suspicious mass on MRI similar to that of average age patients. Additionally, MRI can play an important role in preoperative planning in the old age patients with breast cancer as well as the average age patients.

SS 13 BR-04 16:30
Screening by abbreviated breast MR imaging in women with a history of breast cancer operation
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PURPOSE: To investigate the outcomes of screening abbreviated breast magnetic resonance imaging (AB-MRI), consisting of fat saturated T2-weighted images (fat-sat T2WI), and pre- and one postcontrast acquisition with their derived images in women with a history of breast cancer operation.

MATERIALS AND METHODS: Between October 2014 and April 2016, 778 women (median age, 51 years; age range, 26–84 years) with a history of breast cancer operation underwent AB-MRI for screening. The AB-MRI acquisition time was only 8.5 minutes. Screening mammography (MG), ultrasound (US) and AB-MRI were usually taken on the same day or around the same time in all study population. The reading protocols of AB-MRI consisted of fat-sat T2WI, postcontrast subtracted images, and subtracted maximum-intensity projection (MIP) images. One of three breast radiologists prospectively interpreted AB-MRI with clinical history and prior imaging and reported, according to the BI-RADS 2013. Cancer detection rate, positive predictive value (PPV), sensitivity, specificity, and rate of malignancy of each BI-RADS category were assessed.

RESULTS: 778 women underwent 877 AB-MRI for screening. Among the patients, 679 women underwent one round of screening AB-MRI and 99 women underwent two rounds of screening AB-MRI. During study period, nine cancers in 9 women were diagnosed (4: DCIS, 5: IDC) by AB-MRI. There was no MR occult cancer. Of 9 cancers, four were initially occult on MG and US but subsequent targeted US revealed correlates. PPV for recall, PPV for biopsy, sensitivity and specificity of AB-MRI were 8.8% (9 of 102), 56.3% (9 of 16), 100% (9 of 9), and 99.1% (762 of 769), respectively. The rate of malignancy according to BI-RADS category were 0% in category 1 and 2, 1.1% (1 of 88) in category 3, and 61.5% (8 of 13) in category 4. There was no case of category 5.

CONCLUSION: Screening AB-MRI detected 9 cancers in 778 women (11.6 cancer per 1000 women) and 4 cancers (37.5%) were additionally detected by AB-MR in women with a history of breast cancer operation. Diagnostic performance of AB-MRI was acceptable, and especially, PPV for biopsy was very high (56.3%, 9/16).

SS 13 BR-05 16:40
Diagnostic yield and background parenchymal enhancement change in early breast MR surveillance in women after breast conservation therapy
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PURPOSE: To prospectively investigate the cancer detection yield and background parenchymal enhancement (BPE) change in early breast magnetic resonance (MR) imaging surveillance (12 months or less) in women who had a history of breast conservation therapy (BCT) for breast cancers.

MATERIALS AND METHODS: Between April 2014 and April 2016, 395 consecutive women (mean age, 51.8 ± 9.7 years; age range, 21–81 years) with 403 breast cancers who underwent breast MR imaging for early surveillance (mean, 7.6 ± 2.7 months; range, 2–12 months) after BCT for breast cancer were studied. Of the study population, 382 (94.7%) patients underwent preoperative MR examinations. We assessed cancer detection rate, positive predictive value (PPV), sensitivity, and specificity and evaluated the clinicopathological characteristics of patients with post-operative MR detected cancer. And we evaluated the cancer detection ability in other imaging modalities such as ultrasound and mammography at the same time. In addition, BPE change of contralateral breast was assessed according to post-operative treatment.

RESULTS: 2.0% (8/403) cancers (2 invasive ductal carcinoma [IDC], 5 ductal carcinoma in situ [DCIS], 1 poorly differentiated metastatic carcinoma) were detected with MR imaging. One DCIS was not detected due to prominent BPE initially, and confirmed later with positron emission tomography - computed tomography (PET-CT) correlation. PPV for recall, PPV for biopsy,
sensitivity, and specificity were 25.8% (8/31), 26.6% (8/30), 88.9% (8/9), and 94.4% (371/393). Close resection margin (≤ 0.1 cm) and longer interval between initial surgery and screening MR (> 6 months) were significantly associated with higher cancer detection rate (p = 0.027 and 0.010, respectively). One DCIS was detected on mammography without delineated enhancement on MRI. BPE on early MR surveillance showed significant decrease in all groups with post-operative chemotherapy, hormone therapy and both of the two (p < 0.001).

CONCLUSION: Our data suggest that single-screening MR imaging can be used for early surveillance after BCT, especially in patients with close surgical margin and surveillance interval between 6 and 12 months. And BPE tends to be decreased in very short term follow-up MR in patients with post-operative chemotherapy or hormone therapy.

SS 13 BR-06 16:50
Dynamic contrast-enhanced breast MR imaging in predicting for patterns of recurrence in breast cancer
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PURPOSE: To evaluate pattern of recurrence and the dynamic contrast-enhanced breast MR imaging (DCE-MRI) features influencing recurrence in breast cancer patients.

MATERIALS AND METHODS: From January 2007 to July 2011, we retrospectively reviewed 1030 breast cancer patients who had undergone surgery at our hospital. Among them, we analyzed the DCE-MRI features and clinicopathologic variables of 83 recurrent breast cancer patients. We evaluated the MR imaging features (kinetic curve types, background parenchymal enhancement (BPE), internal enhancement, adjacent vessel sign, whole breast vascularity, initial enhancement pattern, kinetic curve types, and quantitative kinetic parameters) and clinicopathologic variables (multifocality, T stage, nodal status, histologic grade, nuclear grade, extensive intraductal carcinoma component (EIC), hormone receptor, p53, human epidermal growth factor receptor-2 (HER-2), Ki-67, and molecular subtype). The site of recurrence was classified as loco-regional (ipsilateral breast, axilla or supraclavicular fossa) or distant. Univariate and stepwise multivariate regression analysis were performed to evaluate independent risk factors for pattern of recurrence in breast cancer.

RESULTS: Among 1030 women with breast cancers, 41 (4.0%) had loco-regional recurrence and 42 (4.1%) had distant recurrence. Breast MR imaging features independently associated with recurrence were prominent increased ipsilateral whole breast vascularity (OR, 95% CI; 5.82, 2.35–14.55, OR, 95% CI; 3.69, 1.38–9.89), BPE (OR, 95% CI; 2.27, 1.14–4.54, OR, 95% CI; 2.24, 1.11–4.53) for loco-regional and distant metastasis, respectively. Time to peak enhancement (TTP) (OR, 95% CI; 0.38, 0.20–0.71) and the rim enhancement (OR, 95% CI; 5.22, 2.61–10.41) were associated with distant recurrence. In terms of clinicopathologic variables, T stage (OR, 95% CI; 9.40, 2.71–32.67), EIC (OR, 95% CI; 0.29, 0.10–0.82), and histologic grade (OR, 95% CI; 2.99, 1.44–6.26) were associated with distant recurrence. Estrogen receptor (ER) negativity (OR, 95% CI; 0.32, 0.16–0.63) affected only loco-regional recurrence.

CONCLUSION: In dynamic contrast-enhanced breast MR imaging, TTP and the rim enhancement for distant metastasis and prominent increased ipsilateral whole breast-vascularity and BPE for both distant and loco-regional recurrence could be useful to predict pattern of recurrence in patients with breast cancer.

SS 13 BR-07 17:00
Diagnostic performance of breast ultrasound and MRI in prediction of lymph node status after neoadjuvant chemotherapy in breast cancer women
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PURPOSE: To evaluate the diagnostic performance of breast ultrasound and MRI in detection of residual metastatic axillary lymph status after neoadjuvant chemotherapy (NAC) in breast cancer patients and find out any histopathological factors affecting radiological diagnostic performance.

MATERIALS AND METHODS: From January 2010 to December 2010, 261 patients with breast cancer who underwent NAC before operation were retrospectively reviewed. We included 118 patients who underwent both the initial and follow-up preoperative breast MRI and were diagnosed axillary lymph nodal metastasis by initial fine needle aspiration. Of 118 patients also performed the initial and/or follow-up preoperative breast ultrasound. We evaluated sensitivity, specificity, and negative and positive predictive value, accuracy of ultrasound, MRI and combination of imaging modalities
in detecting axillary node involvement after NAC.

RESULTS: After NAC, 43/118 (36%) patients showed negative conversion of ALN on sentinel lymph node or axillary lymph node dissection (ALND). The sensitivity of ultrasound, MRI, and combination in post-NAC axillary imaging was 60%, 57.33%, 65.33% and specificity was 60.47%, 72.09%, 60.47% respectively. The positive predictive value was highest with breast MRI, 78.18%. However, these values were not significantly different. The positive estrogen receptor (ER) was associated with incorrect diagnosis rate of ultrasound (p = 0.002), MRI (p = 0.002) and combination (p = 0.001) on univariate analysis. Also when residual metastatic lymph nodes were present, lymph nodes with macrometastasis (> 2.0 mm) was associated with correct diagnosis rate of ultrasound (p = 0.0027) than micrometastasis (≤ 2.0 mm). On multivariate analysis, size of residual lymph node metastasis and ER status was associated with ultrasound performance [odds ratio, 0.262, 95% CI, 0.079–0.869, odds ratio, 0.476, 95% CI, 0.214–1.058 respectively], but only positive ER status was independently associated with breast MRI [odds ratio 0.419, 95% CI 0.192–0.915] and combined imaging [odds ratio 0.379, 95% CI 0.172–0.838].

CONCLUSION: Breast ultrasound and MRI combination showed highest sensitivity, while MRI alone showed highest specificity and positive predictive value in patients found to be node positive prior to neoadjuvant chemotherapy. Estrogen receptor status and size of residual tumor deposit within the lymph node were associated with the visibility on DBT.

Breast cancer subtype was not a significant factor associated with the visibility on DBT.

CONCLUSION: Breast cancers showed different image findings on DBT according to the subtypes, however, it did not affect the visibility of breast cancers.

SS 13 BR-08  17:10
Imaging features of breast cancers on digital breast tomosynthesis according to the subtypes
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PURPOSE: To evaluate imaging features of breast cancers on digital breast tomosynthesis (DBT) according to the subtypes and to determine whether it affects the visibility of breast cancers on DBT.

MATERIALS AND METHODS: This study was approved by our institutional review board and the requirement for written informed consent was waived. Between December 2011 and February 2014, a retrospective database review identified 277 invasive breast cancers in 273 women who underwent DBT for preoperative evaluation. Three blinded radiologists independently reviewed DBT images to determine the visibility of cancers and morphologies in terms of mass and microcalcification. Visibility score of each breast cancer was determined by the number of readers correctly detected the cancer (0–3) and divided into low (0–1) and high (2–3) visibility groups. Morphologies of breast cancers were reviewed by two unblinded readers in consensus. Clinicopathologic factors associated with the visibility groups were evaluated using chi-square tests or independent samples t-test. Morphologic imaging features of breast cancer subtypes were analyzed using chi-square tests.

RESULTS: The median age was 49 years (range, 22–78). Breast density was almost entirely fatty in 4% (11/273), scattered fibroglandular in 16% (44/273), heterogeneously dense in 58% (159/273), and extremely dense in 22% (59/273). Of 277 invasive cancers (mean size 2.2 cm; range, 0.2–9.5 cm), 186 (67%) were HR(+)HER2(-), 47 (17%) were HR(+/-)HER2(+), and 44 (16%) were HR(-)HER2(-). The most common findings on DBT was spiculated mass for HR(+)HER2(-) cancers; fine linear branching microcalcifications with non-spiculated mass for HR(+/-)HER2(+) cancers; and non-spiculated mass without microcalcification for HR(-)HER2(-) cancers (P<0.001). Low visibility of breast cancers on DBT was more frequent in extremely dense breasts (P=0.020), small pathologic tumor size (P<0.001). Breast cancer subtype was not a significant factor associated with the visibility on DBT.

CONCLUSION: Breast cancers showed different image findings on DBT according to the subtypes, however, it did not affect the visibility of breast cancers.

SS 13 BR-09  17:20
Comparative analysis of images obtained using optimized grid and grid suppression software in diagnosis of microlesions
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PURPOSE: We compared images obtained using optimized grid versus images with Moire artifacts eliminated by grid suppression software.

MATERIALS AND METHODS: We used the mammographic phantom to evaluate microlesions and the resolution chart of the NORMI-13 phantom to analyze changes in the contrast of microfractures. The non-grid, grid suppression, and optimized grid images were compared to analyze the morphological similarities of lesions in the phantoms. In addition, microcalcifications and fractures were induced in rats aged 4 to 6 weeks, and the changes in the contrast and morphology of the lesions were evaluated on images obtained using the
same three methods as in the phantom experiment. Microcalcifications were injected into the abdominal fat of rats, and fractures were generated by dropping a 1 kg weight on their lower legs from 20 cm above.

RESULTS: After grid suppression, microcalcifications in the phantoms showed a contrast decrease of 25–30%; as their margins became gradated, their areas expanded by 10–15%. The image obtained using the optimized grid exhibited a contrast increase of 7–14%. While the resolution chart line of the NORMI-13 phantom showed a 10% contrast decrease in the optimized grid image, the contrast decreased by 70% in the image obtained through the grid suppression software, resulting in a substantial image loss that made it difficult to distinguish the lines. In the rat images, after grid suppression, one of the 14 injected microcalcifications was lost on the image; furthermore, since the margins of the remaining calcifications became gradated, their original forms could not be determined. Similarly, as the contrast and sharpness of the fractures decreased dramatically, it was difficult to diagnose some fracture lines. All of the injected microcalcifications were identified in the optimized grid image; the margins of calcifications and the fracture lines were also clearly identified.

CONCLUSION: We confirmed that grid suppression software affects the diagnosis and identification of microlesions. In order to create high quality images by removing scattered radiations without any loss of image, an optimized grid should be used.

**SS 13 BR-10 17:30**

**Semi-quantitative strain ratio in the differential diagnosis of breast masses: measurements using one region-of-interest**

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**PURPOSE:** To evaluate the diagnostic performances of semi-quantitative strain ratio measured by using one region-of-interest (ROI) on breast US elastography images.

**MATERIALS AND METHODS:** From June to August 2015, 201 breast masses of 165 women (mean age, 47.2 years; range, 18 to 81 years) who underwent breast ultrasound with ultrasound CAD system (S-detect™) were enrolled and underwent breast ultrasound with ultrasound CAD system (S-detect™). Among 269 breast lesions, 30 lesions had been confirmed as malignant after core-needle biopsy or surgery. Other 239 breast lesions had been diagnosed as benign histologically or stable for more than 2 years. We assessed accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). In addition, we evaluated causes and patterns of misinterpretation in false positive and negative groups.

**RESULTS:** Accuracy, sensitivity, specificity, PPV and NPV of breast ultrasound CAD were 75.1%, 80.0%, 74.5%, 28.2 and 96.7%, respectively. Six false negative lesions were all oval in shape and parallel in orientation.
Among 61 false positive lesions, 27 lesions were benign lesions with suspicious features such as fat necrosis or post-operative change. Second leading cause of misinterpretation was inappropriate demarcation of lesions due to heterogeneous echogenicity, large size, adjacent parenchyma or posterior acoustic shadowing. Seven lesions with suspicious features with good demarcation and proper description were confirmed as benign histologically. And 6 lesions with good demarcation and descriptions implying benignity showed possible malignancy as a final conclusion.

**CONCLUSION:** Breast ultrasound CAD is expected to be helpful in avoiding unnecessary biopsy due to its high NPV. And operators need to know characteristics of lesions prone to misinterpretation and to consider clinical history and findings of other imaging modality.

**SS 13 BR-12 17:50**  
Diagnostic performance of CAD in breast ultrasound and factors leading false results  
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**PURPOSE:** To evaluate the diagnostic performance of computer-aided diagnosis (CAD) in assessing breast lesions on ultrasound (US) and to analyze the factors causing false positive or false negative results.

**MATERIALS AND METHODS:** One hundred and thirteen consecutive patients with 149 breast lesions which were confirmed histologically (n = 82) or by stable benign morphology for more than 2 years (n = 67), constituted this prospective study. Breast ultrasound examination was performed by one of 5 breast dedicated radiologists and final assessment according to the Breast Imaging Reporting and Data System (BI-RADS) was recorded. One radiologist who did not perform the US examination and was blind to the final diagnosis applied the US-CAD system (Smart-Detect™ Samsung Medison Co., Ltd, Seoul, Korea) on the stored US images of breast lesions. CAD system was applied twice for each breast lesion on transverse and sagittal images. Malignancy was considered when any of the two results was malignant. We analyzed the accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of final assessment by radiologists and CAD, and analyzed the factors of CAD leading to false results.

**RESULTS:** Overall sensitivity, specificity, PPV and NPV of CAD and radiologist were 92.3% vs. 100%, 88.7% vs. 77.3%, 81.4% vs. 70.3%, and 95.6% vs. 100%. Since the cancer rate of assessment BI-RADS category 4A results were considered benign, the sensitivity, specificity, PPV, and NPV improved to 98.1%, 99.0%, 98.1% and 99.0%. Among the 15 cases which were misdiagnosed by CAD, 11 showed false positive and 4 showed false negative results. Two of 11 false positive cases were considered as BI-RADS category 2 by radiologists, but due to their irregular shape and microlobulated or indistinct margin, typical hamartoma and hematoma were considered malignant by CAD. Four false negative cases were assessed as BI-RADS category 4B or 4C by radiologists, but CAD analyzed them as benign due to their margin or lesion boundary.

**CONCLUSION:** CAD showed good performance comparable to radiologists. But specific benign lesions with atypical benign findings can be misdiagnosed by CAD and wrong analysis of margin was frequently observed in false negative result of CAD.

**SS 21 BR-01 09:50**  
Perfusion parameters at dynamic contrast-enhanced breast MR imaging are associated with disease-specific survival in patients with triple-negative breast cancer  
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**PURPOSE:** To investigate the association between perfusion parameters in pretreatment MR imaging and survival outcome (disease-free survival [DFS], disease-specific survival [DSS]) in patients with triple negative breast cancer (TNBC).

**MATERIALS AND METHODS:** Sixty-one patients (median age, 50 years; range, 27–77 years) with TNBC (median size on MR imaging, 255 mm; range, 11–142 mm) who underwent pretreatment MR imaging between November 2010 and August 2012 were included. We analyzed clinical-pathologic variables and MR imaging parameters (including SER, peak enhancement, $K_{trans}$, $K_{ep}$, $v_e$). Calculation of perfusion parameters was...
performed with dedicated post-processing software, using a semi-automated segmentation method. Cox proportional hazards models were used to determine associations between survival outcome and 1) variables obtainable before treatment (age, menopausal status, MR imaging features, preoperative diagnosis of lymph node metastasis) and 2) post-treatment clinical-pathologic variables.

RESULTS: The median follow-up time was 46.1 months (range, 6.3–58.4 months). Eleven of 61 (18.0%) patients had events and seven (11.4%) died from breast cancer. Among pretreatment variables, a larger tumor size on MR images (hazard ratio [HR] = 1.024, p = 0.003) was associated with worse DFS at univariate analysis. In multivariate pretreatment models for DSS, a higher \( v_e \) value (HR = 1.658, p = 0.038), higher peak enhancement (HR = 1.843, p = 0.018) and a larger tumor size on MR images (HR = 1.060, p = 0.001) were associated with worse DSS. In multivariate post-treatment models, a larger pathologic tumor size (HR for DFS, 1.074 [p = 0.005]; HR for DSS, 1.050 [p = 0.042]) and metastasis in surgically resected axillary lymph nodes (HR for DFS, 5.789 [p = 0.017]; HR for DSS, 23.717 [p = 0.002]) were associated with worse survival outcome.

CONCLUSION: A higher \( v_e \) value, peak enhancement and larger tumor size of the primary tumor at pretreatment MR imaging were independent predictors of worse DSS in TNBC patients.

SS 21 BR-02 10:00
Computer-aided detection (CAD)-generated kinetic features of preoperative breast MR imaging: association with disease-free survival of patients with invasive breast cancer
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PURPOSE: To retrospectively investigate whether the kinetic features of breast cancers assessed with computer-aided detection (CAD) at preoperative magnetic resonance (MR) imaging are associated with disease-free survival in patients with invasive breast cancer.

MATERIALS AND METHODS: This is an Institutional Review Board-approved retrospective study, with a waiver of informed consent. A total of 121 invasive breast cancers (mean size, 2.3 ± 1.5 cm) in 121 women (mean age, 52.2 years; range, 24–78 years) who underwent preoperative 3D and 2D SWE and surgery were included. The mean elasticity values (kPa) of each lesion were measured by an experienced radiologist on both 3D and 2D SWE images. Associations among these mean values with prognostic factors (tumor size, axillary nodal status, histological grade, lymphovascular invasion, estrogen receptor [ER], progesterone receptor [PR] status, human epidermal growth factor receptor-2 (HER2) status, and presence of lymphovascular invasion) were assessed using univariate and multivariate Cox proportional hazards regression models.

RESULTS: The median follow-up time was 42 months (range, 3–50 months). Multivariate Cox's analysis showed that a higher mean elasticity value (HR = 1.01, 95% confidence interval [CI] = 1.00–1.01, p = 0.01) and presence of lymphovascular invasion (HR = 2.43, 95% CI = 1.09–5.45, p = 0.03) were independently associated with poorer disease-free survival.

CONCLUSION: A higher CAD-measured peak enhancement at preoperative breast MR imaging was independently associated with poorer disease-free survival of patients with invasive breast cancer.
[HER2], Ki-67, and p53 status) and tumor subtypes (ER-positive, HER2-positive, triple-negative) were analyzed using univariate and multivariate logistic regression analyses.

**RESULTS:** The mean elasticity values of the 121 breast cancers were not significantly different between 3D and 2D SWE (122.98 ± 49.58 vs. 126.04 ± 63.85, p = 0.384). On both 3D and 2D SWE, a larger tumor size, a higher histological grade (grade 3), the presence of lymphovascular invasion, ER negativity, PR negativity, HER2 positivity, and higher expression of Ki-67 (≥ 14%) were significantly associated with higher mean elasticity values (all p values < 0.05). The triple-negative tumor subtype was also associated with higher mean elasticity value (p < 0.05) upon both 3D and 2D SWE. By multivariate linear regression, the following variables were independently associated with the mean elasticity values: tumor size (p = 0.002) and histological grade (p = 0.034) on 3D SWE; and tumor size (p = 0.013), histological grade (p = 0.048), and the presence of lymphovascular invasion (p = 0.017) on 2D SWE.

**CONCLUSION:** In patients with invasive breast cancer, both tumor size and histological grade independently influenced the mean elasticity values obtained using either 3D or 2D SWE. However, the tumor subtype was not so associated.

**SS 21 BR-05 10:30**  
Preoperative MR imaging features associated with distant metastasis-free survival in breast cancer patients

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**PURPOSE:** To determine the magnetic resonance (MR) imaging findings and clinical-pathologic factors associated with recurrence in patients with triple-negative breast cancer.

**MATERIALS AND METHODS:** This study was approved by the Institutional Review Board, and the informed consent for enrolled patients was waived. Two hundred and twenty three patients with surgically confirmed triple-negative breast cancer (median age, 50 years; range, 24–82 years) who were treated between January 2009 and March 2016 and underwent preoperative breast MR imaging with diffusion-weighted (DW) imaging were included in this study. Visual assessment of central T2 high signal intensity and fibroglandular volume (FGV) on T2WI, rim-enhancement, background parenchymal enhancement (BPE) on post-contrast T1WI and, peripheral high signal intensity on DWI were performed. Measurement of ADC values of the whole tumor was performed. Clinical-pathologic data were collected including patient age, histologic tumor grade, invasive tumor size, lymphovascular invasion, lymph node involvement, margin status, multiplicity and Ki-67. Statistics for relative risk of recurrence carried out using Pearson’s Chi-square test. Multivariate analysis was performed by using a Cox proportional hazards model, and recurrence-free survival was estimated with the adjusted Kaplan-Meier method.

**RESULTS:** Of the 223 lesions, 30 (13.5%) lesions were recurred after a median follow-up of 37 months. The LVI (hazard ratio [HR] with multivariate analysis = 3.48; 95% confidence interval = 1.61, 7.54; p = 0.002), lymph node involvement (HR = 3.14; 95% confidence interval = 1.51, 6.51; p = 0.002), and advanced stage (HR = 3.02; 95% confidence interval = 1.45, 6.29; p = 0.003) were found to be independently associated with recurrence. Rim-enhancement (p = 0.006) was significantly associated with recurrence in patients with triple-negative cancer. While, central T2 high signal intensity, FGV, BPE, peripheral high signal intensity on DWI, whole ADC values were not significantly associated with recurrence.

**CONCLUSION:** The LVI, lymph node involvement, advanced stage and rim-enhancement on preoperative MRI were associated with an increased risk of recurrence in patients with triple-negative breast cancer.
regression.

**RESULTS:** Rim enhancement (hazard ratio [HR] = 1.55; 95% confidence interval [CI] = 1.07, 2.23; p = 0.019) was the only significant feature associated with worse DM-free survival. In the subgroup analysis according to molecular subtypes, significant feature was rim enhancement for triple negative subtype (HR = 2.55, 95% CI = 1.16, 5.59; p = 0.019), amount of fibroglandular tissue for luminal subtype (HR = 0.49, 95% CI = 0.25, 0.95; p = 0.036), and associated features for HER2-enriched subtype (HR = 2.52, 95% CI = 1.05, 6.03; p = 0.038). The presence of peritumoral edema on T2-weighted images (odds ratio = 2.71; 95% CI = 1.30, 5.63; p = 0.007) was associated with early DM.

**CONCLUSION:** Rim enhancement on preoperative MR imaging was the independent imaging feature associated with worse DM-free survival in breast cancer patients, particularly in triple negative subtypes.

**SS 21 BR-06 10:40**

**Characteristics and survival outcome of screening US-detected breast cancers**

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**PURPOSE:** To investigate clinical, imaging and pathological characteristics and outcomes of mammography-negative and ultrasound (US)-detected breast cancers.

**MATERIALS AND METHODS:** Among women who received surgery for breast cancers from January 2004 to March 2011 at four institutions, asymptomatic women who had mammography-negative and US-detected breast cancers were identified. Women with personal history of breast or other organ cancer or women with <5 years of follow-up period after surgery were excluded. Finally, a total of 521 women (median age, 47 years; range, 27–74) were included. Clinical, imaging, and pathologic characteristics of US-detected cancers were analyzed. Recurrence event and pattern was analyzed. Kaplan-Meier analysis was performed to calculate recurrence-free survival (RFS). Cox proportional hazard analysis was performed to determine the patient and disease characteristics associated with recurrence.

**RESULTS:** Four hundred and forty two (84.8%) had invasive breast cancers and 79 (15.2%) had ductal carcinoma in situ (DCIS). Four hundred and sixty three (88.9%) received breast conserving, 58 (11.1%) received total mastectomy and 439 (84.3%) received adjuvant endocrine therapy. Of 442 invasive cancers, 54 (12.2%) had lymph node metastases and 191 (43.2%) received chemotherapy. Of 442 invasive cancers, 361 (81.7%) were TNM stage I, 72 (16.3%) were stage II, and 9 (2.0%) were stage III. Invasive cancers were classified as 354 (80.1%) hormone receptor (HR)-positive/HER2-negative, 28 (6.3%) HR-positive/HER2-positive, 17 (3.8%) HR-negative/HER2-positive, and 43 (9.7%) triple negative. At a median follow-up of 7 years (range, 5–12 years), there were 17 (3.3%) recurrences. The 5-year RFS was 97.9% and 10-year RFS was 96.7%. Among 17 recurrences, 14 were invasive cancers (9 in contralateral breast, 4 in ipsilateral breast and 1 distant metastasis in lung), and 3 were DCIS (2 in contralateral breast and 1 in ipsilateral breast). There were no deaths. In women with DCIS, tumor size was only associated with recurrence. In women with invasive cancers, triple negative (Hazard ratio, 5.767; 95% confidence interval, 1.902–17.492; p = 0.002), nipple distance ≤ 2 cm (3.069; 1.058–8.896; p = 0.039) and BI-RADS category 4a (4.557; 1.519–13.793; p = 0.007) were independently associated with recurrence in multivariate analysis.

**CONCLUSION:** Most women with US-detected breast cancers have an excellent outcome.

**SS 21 BR-07 10:50**

**Should the axilla be included in screening ultrasound?**

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**PURPOSE:** To evaluate the outcome of routine bilateral axillary scanning while performing supplemental screening ultrasound (US).

**MATERIALS AND METHODS:** This retrospective study was approved by our Institutional Review Board and the requirement for written informed consent was waived. Between January 2012 and December 2014, 20327 supplemental screening US examinations were performed in 13056 women with negative mammograms at a single health screening center. Bilateral whole breast US examinations were performed with a handheld device by experienced radiologists and bilateral axillary regions were routinely scanned and representative images were documented. The abnormal interpretation rates, cancer detection rates, and positive predictive values (PPVs) of supplemental screening US for the breasts only and both breasts and axillae were calculated, respectively.

**RESULTS:** Of 13056 women, 12624 (97%) were at
low risk and 432 (3%) were at intermediate-to-high risk for breast cancer. Bilateral whole breast US showed positive results in 1715 exams (abnormal interpretation rate, 8.4% [1715/20327]) and detected 27 breast cancers (cancer detection rate, 1.3 per 1000 exams) with PPV (abnormal interpretation) of 1.6% (27/1715) and PPV3 (biopsy performed) of 7.8% (23/295). Bilateral axillary US showed positive results in 46 exams (with negative results on bilateral whole breast US in 34 exams; positive results on bilateral whole breast US in 12 exams) which yielded no malignancy by follow-up (n = 33), core needle biopsy (n = 12), or fine needle aspiration (n = 1). The abnormal interpretation rate of supplemental screening US for the both breasts and axillae minimally increased to 8.6% [1749/20327]. The PPVs slightly decreased (PPV1, 1.5% [27/1749]; PPV3, 7.5% [23/307]) without changes in the cancer detection rate.

CONCLUSION: Routine bilateral axillary scanning had no effects on the cancer detection rates of supplemental screening US, however increased false-positive findings.

SS 21 BR-08  11:00
The efficacy of US for detection of axillary lymph node recurrence: 5-year surveillance in breast cancer patients treated with sentinel lymph node biopsy (SLNB)
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PURPOSE: Screening the axilla remains elective in US screening for breast cancer and the efficacy of screening US for axillary recurrence in breast cancer patients treated with sentinel lymph node biopsy (SLNB) is unclear. The purpose of this study was to determine the efficacy of screening US in breast cancer patient treated with SLNB for evaluation of recurrences in breasts and axillae.

MATERIALS AND METHODS: A retrospective chart review was performed on 367 consecutive patients who were treated with SLNB between January and June 2011. Among these, 303 patients who received annual follow-up screening during 5 years were included. Whole breast ultrasounds including both breasts, excision sites, and axillae were performed and interpreted by expert breast radiologists with mammographic information. The cancer detection rate, recall rate, and positive predictive value (PPV3) of biopsies in breasts and axillae were calculated separately on the basis of pathology or follow-up data.

RESULTS: A total 303 patients underwent 2045 screening US combined with MG during 5-year follow-up period, 12 had recurrences (5.87 per 1000 cases) including one axillary recurrence (0.49 per 1000 cases), and 8 occurred within the third year and 4 occurred in the fourth and fifth year. Among recurred breast cancers, 8 breast lesions were detected by combined US and MG with 5-year accumulated cancer detection rate of 3.91 per 1,000 cases. Axillary recurrence was detected on chest CT scan by minimal size change, not by US. During the period, 244 cases were recalled for breast (11.9%), and 33 cases for axillary lesion (1.6%), and US-guided biopsy was performed in 38 breasts and 10 axillary findings, respectively. The PPV3 for breast was 26.3%, and 0% for axilla.

CONCLUSION: Screening US combined with MG detected 3.91 recurrent cancers per 1,000 cases for 5-year follow-up period in breast cancer patients treated with SNLB. Axillary recurrence was very rare compared to in-breast recurrence and screening the axilla was not helpful for detecting axillary recurrence, although the recall rate is lower than that of breast lesions.

CLINICAL RELEVANCE: Our study supports the benefit of screening axillae in patient treated with SNLB is minimal, even though the recall rate is not as high as screening breasts.

SS 21 BR-09  11:10
Predictive factors of residual metastatic axillary lymph node disease with negative axillary imaging after neoadjuvant chemotherapy for primary breast cancer
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PURPOSE: To evaluate predictive factors affecting residual metastatic axillary lymph node (ALN) disease with negative axillary imaging after neoadjuvant chemotherapy in breast cancer.

MATERIALS AND METHODS: From January 2011 to December 2015, 206 patients with breast cancers who underwent neoadjuvant chemotherapy (NAC) and curative surgery were retrospectively reviewed. Among them, 154 patients (74.6%; mean age, 46.7 years) showed negative axillary imaging including ultrasound, MRI and PET/CT after NAC. Collected data included age, clinical T, N stage, initial tumor size, histologic grade, hormonal receptor (HR), human epidermal growth factor receptor 2 (HER2), Ki-67, and percent tumor size change (≥ 30% decrease, < 30% decrease). Multivariate logistic regression analysis was performed between patients with and without residual metastatic ALN disease.

RESULTS: Of the 154 patients who showed negative
axillary imaging, 55 patients (35.7%, 95% confidence interval [CI]: 26.9–46.5%) had residual metastatic ALN disease on surgical histology. Among them, 78.1% (43/55) and 21.8% (12/55) showed 1–3 (ypN1) and more than 4 metastatic ALNs (≥ ypN2). Clinical N stage (p = 0.038), low to moderate tumor grade (odd ratio [OR] = 7.0, p = 0.005), positive HR status (OR = 7.2, p = 0.002), negative HER-2 status (OR = 2.7, p = 0.049) and percentage tumor size change less than 30% (OR = 4.8, p = 0.011) were independently associated with residual metastatic ALN disease.

CONCLUSION: Initial clinical N stage, tumor grade, HR and HER2 status, and percent tumor size change are possible predictors for residual metastatic ALN disease.